A comparative study of the roots of Ranunculaceæ.

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WITH PLATES II—IV.

(Continued from p. 47.)

V. A study of the meristem.

In the studies thus far made, the roots of *Ranunculaceæ* have all been assigned to one type, as regards their apical meristem structure, this being Erickson's third type and Janczewski's fourth. My investigations indicate that the roots do not all follow this type, some agreeing with Janczewski's third type, and on account of a modification of structure for two species, I have provisionally formed another subsidiary type.

I have not thought it necessary to describe and figure the meristem of each particular species, but will define the type, describe one representative species under it and then name the other species found to agree with this type.

1. My first type includes roots having three primary meristem tissues, the plerome, the periblem, and, in Erickson's phrase, the dermocalyptrogen, the root-cap and epidermis having a common origin. This will be seen to be Janczewski's third type, corresponding to Erickson's first type for dicotyledons. As an example of this type I describe the structure of the root tip of *Ranunculus sceleratus.*[1] In this root the epidermis can be traced from above the root-cap, thence passing beneath its layers, and ending as a distinct layer at a point near the tip of the central cylinder, as shown at *a* in the figure: at this point the cells lose their epidermal character, divide and merge into the tissue of the root-cap; the cortex, however, is distinct from the tissues on either side even at the tip, though here it is reduced to about two rows of cells, and presents an initial group of its own; likewise the central cylinder is distinctly separated from the cortex by a continuous endodermis, its initial group consisting of a few cells at the tip, thus presenting, as already pointed out, a plerome, *pl*, a periblem, *p*, and a combined initial group for the epidermis and root-cap, the dermocalyptrogen, *dc.* The other species found to agree with this in structure are: *R. circinatus*, *R. aquatilis* var. *trichophyllus*, *Clematis*

[1] Plate IV, fig. 30.

verticillaris and probably *R. repens*, *R. bulbosus* and *R. fascicularis*, though in the last three species the roots at the very tip show to a certain degree a blending of tissues, and perhaps the plerome and periblem could be said to coalesce with the dermocalyptrogen and so belong to Erickson's third type. He certainly says *R. repens* belongs there, but my sections would indicate that the plerome and periblem were distinct in origin though slightly confused by later growth.

The roots of two plants examined differed from the first type only in that the epidermis can be traced as a distinct layer entirely about the periblem, while in the first type the epidermis ended as a distinct layer before the vegetative point was reached. In this, as in the first type, the root-cap is derived from the epidermis, for though the epidermis can be traced entirely around the vegetative point, it gives off layers of cells which are distinctly a part of the root-cap. This variation from the first type is so slight as to warrant us at most in simply establishing a subsidiary type. The structure for this subsidiary type is shown for *Ranunculus Pennsylvanicus* in plate IV, fig. 31. The epidermis is distinctly traced both by its peculiar appearance and by being a continuous, unbroken layer entirely about the tip of the cortex; the origin of root-cap cells from this layer is indicated at *a* and *b* of the figure; the cortex is of several rows of cells which are reduced to two at the tip and do not coalesce with either the epidermis on one side or the central cylinder on the other. Thus we find a distinct plerome, *pl*, and periblem, *p*, and a combined dermocalyptrogen, *dc*. It differs from the first type only in that the epidermis does not lose its identity, though giving birth to the root-cap by cell-division on its exterior side. The only other plant I certainly place in this provisional type is *R. acris*. Other species with doubt referred to the first type may possibly belong to this subsidiary type.

2. My second main type corresponds to Erickson's third type in which all the tissues merge into one at the vegetative point, that is, the initial group is a common one for all tissues. As an example of this type I have taken the root tip of *Aconitum Noveboracense*.[2] In this root the epidermis is seen to be of cells which are larger than the other cells of the root tip, and can be traced from above the root cap, thence

[2] Plate IV, figs. 32, 33.

beneath its upward projecting layers, but ending as a distinct layer at about 1^{mm} from the tip of the central cylinder, represented at *a* in the figure. Here the layer loses its epidermal character and divides to merge into the tissues of the root cap, as in the first type, the cortex of several rows of cells could be traced as distinct layers to within about 5^{mm} of the tip of the central cylinder where they divided irregularly and appeared to coalesce with the epidermal[3] and root cap tissues of this region, as shown at *b* in the figure, the central cylinder as bounded by the endodermis was distinct to within a small fraction of a millimeter from the tip, where its rows of cells ended as distinct rows and its tissues merge into those of the cortex, as shown at *i* in the figure. Thus we see that all the tissues run together at the vegetative point and the initial group is a common one.

In this type I also include : *Anemone Virginiana* and its var. *alba*, *Actæa alba*, *A. spicata* var. *rubra*, *Hepatica acutiloba*, *H. triloba*, *Cimicifuga racemosa*, *Hydrastis Canadensis*, *Trollius laxus*, *Thalictrum dioicum*, and perhaps *Ranunculus septentrionalis*, though in this latter case the plerome and periblem almost appeared to be distinct, and if so it belongs to the first type.

While I have made these three types of meristem structure for the roots of *Ranunculaceæ*, my examination has shown me that there are no hard and fast lines circumscribing these types but there are all gradations between the structure as found in *Ranunculus Pennsylvanicus*, in which the epidermis could be traced distinctly about the vegetative point, to that found in the roots of *Aconitum Noveboracense* in which the tissues quite evidently coalesced at the vegetative point. It will be seen that the larger number of species are placed in the second main type, which is the type to which the *Ranunculaceæ* studied by Erickson and Flahault were assigned, these writers being the only ones, as far as I have been able to find, who have studied the meristem of any of the *Ranunculaceæ*, and the few species they studied were mainly those not found in this country.

Of some of the species taken for study, I was unable to obtain sections of the vegetative point that showed the meristem

[3]The epidermis in this as in most of the roots studied stained differently and had an entirely different appearance, and could easily be distinguished from any other tissue.

structure, some on account of the very minute root tips, as *Anemone thalictroides* and *Coptis trifolia;* others failed of success since the material first gathered proved to be poor and then the ground had become frozen and I was unable to obtain more material. Among these latter plants, are *Thalictrum polygamum*, *Anemone Pennsylvanica*, *Ranunculus recurvatus*, *Clematis Virginiana*, *Aquilegia Canadensis* and *Caltha palustris*.

The assigning of the species to the types as I have placed them may be but provisional, for though I had sections of several root tips from each species in almost all cases, yet sometimes two sections from different roots of the same species did not appear exactly alike in their terminal structure, and a study of a greater number of roots might necessitate changing some plants from one type to another, but they certainly do not all fall under one type of structure,[4] as indicated by Erickson.

VI. Summary.

1. *Changes through secondary growth.*

In discussing the differences found in the several species of *Ranunculaceæ* examined, I have made three types of structure on the basis of the changes taking place through secondary growth.

First, those plants which show no marked change of root structure, the primitive radial type of structure persisting in the older roots. In this class I include *Ranunculus acris*, *R. Pennsylvanicus*, *R. recurvatus*, *R. septentrionalis*, *R. hispidus*, *R. fascicularis*, *R. bulbosus*, *R. multifidus*, *R. circinatus*, *R. aquatilis* var. *trichophyllus*, *Hepatica acutiloba*, *H. triloba*, *Aconitum Noveboracense*, *Trollius laxus*, and *Caltha palustris*.

Second, those plants showing a greatly marked change in the bundle area through growth of secondary xylem rays, which by their great development conceal the primitive radial type as found in the younger roots. To this class belong *Clematis Virginiana*, *C. verticillaris*, *Cimicifuga racemosa*, *Actæa alba*, *A. spicata* var. *rubra*, *Anemone Virginiana* and its var. *alba*, *A. Pennsylvanica*, *Coptis trifolia*, *Hydrastis Canadensis* and *Ranunculus sceleratus*.

Third, those plants which show in the older roots a great

[4] My study has all been upon the mature root.

development of the central cylinder and a corresponding decrease of the cortex region. This change is partly brought about by the increase of conjunctive parenchyma in the central cylinder, the xylem being all collected at the center and the phloem in several scattered rays radiating from this center. But the decrease in the cortex region of the oldest roots is mainly due to exfoliation, the epidermis and in some cases all but two rows of the cortex cells being thrown off, so that the endodermis, consisting of many very small regular cells whose walls are generally cutinized, now serves the purpose of an epidermis. This exfoliation was especially noted in the Thalictrums studied. In this type are placed but four of the plants that came under my study, viz.: *Thalictrum dioicum*, *T. polygamum*, *Anemonella thalictroides* and *Aquilegia Canadensis*.

2. *Meristem of vegetative point.*

I have found that the roots of the *Ranunculaceæ* do not all fall under one type of apical meristem structure, but that there are two main types and a possible subsidiary type to be recognized in these roots.

First, a type having a distinct plerome and periblem and a combined dermocalyptrogen. In this type I have placed *Ranunculus sceleratus*, *R. circinatus*, *R. aquatilis* var. *trichophyllus*, *Clematis verticillaris*, and probably *R. repens*, *R. fascicularis* and *R. bulbosus*.

Subsidiary type, like the first type except that the epidermis is a distinct layer entirely about the vegetative point, though giving birth to the root-cap and so having the same initial groups as the first type. Here are included but two species, *Ranunculus acris*, and *R. Pennsylvanicus*.

Second, a type in which all the tissues coalesce at the vegetative point, having but one, and this a common, initial group. This type includes the greater number of species studied and is the type in which Erickson and Flahault include the *Ranunculaceæ* studied by them. The species placed in this type are *Aconitum Noveboracense*, *Anemone Virginiana*, and its var. *alba*, *Actæa alba*, *A. spicata* var. *rubra*, *Hepatica acutiloba*, *H. triloba*, *Cimicifuga racemosa*, *Hydrastis Canadensis*, *Trollius laxis*, *Thalictrum dioicum* and perhaps *Ranunculus septentrionalis*.

VII. Acknowledgment.

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Chicago.[5]

EXPLANATION OF PLATES II–IV.

Abbreviations used: *e*, epidermis; *c*, cortex; *en*, endodermis; *c c*, central cylinder; *x*, xylem; *ph*, phloem; *pl*, plerome; *p*, periblem; *d c*, dermocalyptrogen.

All figures of transections of roots were from camera lucida drawings; of other figures the outline was from camera lucida drawings and the details were put is free hand. The scale of magnification is indicated with most figures, the line drawn being the magnification of .1^{mm} for the lower powers of the microscope, and of .01^{mm} for the higher powers. Of the drawings of transections of the roots shown in figs. 1 to 25, two drawings have been made of each section, one from a higher power of the microscope, showing the central cylinder, with the xylem and phloem masses, *x* and *ph*, the surrounding conjunctive parenchyma, the enclosing endodermis, *en*, and generally one or more rows of cortex cells, *c*; the other from a ¾^{in} objective simply to show general plan of structure, and relative proportion of cortex and central cylinder, hence only part of the cells are drawn.

PLATE II.—Figs, 1, 2. Ranunculus aquatilis, var. trichophyllus.—Figs. 5, 6. Ranunculus circinatus.—Figs. 5, 6. Ranunculus acris.—Figs. 7, 8. Ranunculus hispidus.—Figs. 9, 10. Ranunculus fascicularis.—Figs. 11, 12. Ranunculus multifidus.

PLATE III.—Figs. 13, 14. Hepatica acutiloba.—Figs. 15, 16. Anemone Virginiana.—Figs. 17, 18. Caltha palustris.—Figs. 19, 21. Actæa alba, young root.—Fig. 20. Actæa spicata, var. rubra.—Figs. 22, 23. Aconitum Noveboracense.

PLATE IV.—Fig. 24. Clematis Virginiana, older root.—Fig. 25. The same, young root.—Fig. 26. Cimicifuga racemosa, young root.—Fig. 27. The same, older root.—Fig. 28. Thalictrum polygamum, young root.—Fig. 29. Thalictrum dioicum, older root.—Fig. 30. Ranunculus sceleratus, root tip.—Fig. 31. Ranunculus Pennsylvanicus, root tip.—Fig. 32. Aconitum Noveboracense, root tip.—Fig. 33. The same, diagrammatic figure.

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[5]At the close of the two preceding parts of this paper strike out the words *University of*, as the author has no connection with the University of Chicago.